

**Effects of Proposed Virginia CAIR Rule Prohibition on  
Purchasing Allowances in Nonattainment Areas for  
CAIR Sources on 8-Hour Ozone and PM<sub>2.5</sub> Attainment**

Prepared for:

Mirant Potomac River, LLC

Prepared by:

Ralph Morris  
Alan Kao

ENVIRON International Corporation

101 Rowland Way  
Novato, CA 94945

And

8 Hollis Street  
Groton, Massachusetts 01450

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## EXECUTIVE SUMMARY

ENVIRON International Corporation has been retained to compare the ambient air quality impacts in Virginia nonattainment areas for two future-year (2009) emission scenarios: compliance with Clean Air Interstate Rule ("CAIR") limitations by allowing purchase of emission allowances (2009 Purchasing) versus compliance with CAIR limitations where purchase of such allowances is prohibited (2009 No Purchasing in Nonattainment areas). We have made this comparison using the Association for Southeastern Integrated Planning ("ASIP") modeling database that is being used by several states to demonstrate attainment of the 8-hour ozone and fine particulate matter (PM<sub>2.5</sub>) air quality standards. Our modeling demonstrates that there is no measurable air quality benefit to prohibiting trading in nonattainment areas. Complex computer modeling taking into account the photochemical and other chemical reactions involved in ozone and PM<sub>2.5</sub> formations predicts ambient concentrations that are virtually indistinguishable under the two scenarios. An evaluation of the underlying atmospheric chemistry supports the modeling conclusion and also indicates that actual air quality is also likely to be better than predicted by the models. This conservatism, or overstatement of impacts, is due to certain assumptions in the modeling that the NO<sub>x</sub> is dispersed immediately rather than the gradual dispersion which actually occurs in the real atmosphere. This modeling is also consistent with the public policy of the CAIR to address regional transport of pollutants and not local nonattainment issues. Moreover, this report explains why prohibiting trading could lead to local increases in ozone formation, again due to the chemistry within plumes.

## 1. INTRODUCTION

### BACKGROUND

#### Background on CAIR

On 12 May 2005, EPA published in the Federal Register the final Clean Air Interstate Rule (CAIR) imposing controls on sulfur dioxide (SO<sub>2</sub>) and oxides of nitrogen (NO<sub>x</sub>) to assist in achieving attainment of the 8-hour ozone and fine particulate (PM<sub>2.5</sub>) standards in the eastern United States (Fed Reg., 2005). The CAIR Rule mandates the deepest cuts in sulfur dioxide and nitrogen oxides emissions in more than a decade. It provides for the use of a regional cap-and-trade program aimed at achieving the substantial reductions SO<sub>2</sub> and NO<sub>x</sub> emissions in order to help attain the 8-hour ozone and PM<sub>2.5</sub> National Ambient Air Quality Standards (NAAQS). The program applies to the 28 eastern states and the District of Columbia. Though the required emissions reductions could conceivably come from any collection of anthropogenic source categories, the CAIR clearly reflects EPA's position that the mandated substantial emissions reductions should come from the electric generating unit (EGU) sector because, EPA asserts, controls on these sources would be highly cost effective.

In support of the rule, EPA's technical analyses relied upon advanced one-atmosphere regional air quality models, the Community Multi-scale Air Quality (CMAQ; Byun and Ching, 1999) and the Comprehensive Air-quality Model with extensions (CAMx; ENVIRON, 2006) modeling systems, and recent annual meteorological and emissions data bases to assess which upwind states have a "significant" contribution to downwind 8-hour ozone and PM<sub>2.5</sub> nonattainment in the eastern U.S. The CAIR Technical Support Document (EPA, 2005a) also identifies those states that are subject to the ozone (NO<sub>x</sub>) and/or PM<sub>2.5</sub> (SO<sub>2</sub> and NO<sub>x</sub>) control provisions of the rule. As noted, the CAIR SO<sub>2</sub> and/or NO<sub>x</sub> controls would be applied mainly to EGUs in those states that were identified in EPA's CAMx/CMAQ modeling as having a significant contribution to nonattainment. Using these two regional modeling systems, EPA determined that emissions from the State of Virginia, as well as 27 other eastern States, have a significant contribution to downwind 8-hour ozone and PM<sub>2.5</sub> nonattainment so is subject to both the NO<sub>x</sub> and SO<sub>2</sub> emission control provisions of CAIR.

For each EGU in a CAIR State, EPA allocated an allowance of SO<sub>2</sub> emissions (EPA, 2005b) and NO<sub>x</sub> emissions (EPA, 2005c) to come up with that state's SO<sub>2</sub> and NO<sub>x</sub> emissions budgets. As part of CAIR, EPA is implementing a SO<sub>2</sub> and NO<sub>x</sub> cap and trade program for EGU emissions that they believe is highly cost effective and was one of the reasons used to justify the CAIR controls (Fed. Reg., 2005). Under the CAIR cap and trade program, EGUs in all states that opt-in to the program are allowed to comply with the CAIR allocations either by controlling their emissions to the CAIR emissions limits or by purchasing emissions credits from other EGUs in the CAIR cap and trade program that over control beyond their CAIR allowances.

#### Proposed Virginia Regulation for No Emissions Purchasing

The Virginia Department of Environmental Quality (VDEQ) is considering a regulation (9 VAC 5-140 1010 *et seq.*) to prohibit purchasing emissions allowances to comply with CAIR at any EGUs within a nonattainment area (NAA). The only coal fired facility in the Commonwealth of

Virginia that would be subject to this rule is the Mirant Potomac River Generating Station (PRGS) in Alexandria, Virginia.

## **PURPOSE**

Mirant Potomac River, LLC (Mirant) operates the PRGS that is located within the Virginia portion of the Greater Washington D.C. Nonattainment area (NAA), and would therefore be subject to the proposed VDEQ regulation that would not allow compliance with CAIR through the purchase of allowances. Mirant contracted with ENVIRON International Corporation to perform photochemical modeling of the PRGS under two scenarios - - where CAIR allowances can be purchased in NAAs and where such allowances cannot be purchased, and compare to the potential impacts on 8-hour ozone and PM<sub>2.5</sub> attainment in the Washington D.C. NAA and vicinity under each of these scenarios.

## **TECHNICAL APPROACH**

ENVIRON is currently Prime Contractor for the Association for Southeastern Integrated Planning (ASIP), an organization that is conducting photochemical modeling to support 8-hour and PM<sub>2.5</sub> attainment demonstrations in the Southeastern States. ASIP includes the States of Alabama, Georgia, Kentucky, North Carolina, South Carolina, Tennessee, Virginia and West Virginia and local agencies. To perform the ASIP work, ENVIRON is contracted through the Southeastern States Air Resource Managers, Inc. (SESARM; <http://www.metro4-sesarm.org/>). The Community Multiscale Air Quality (CMAQ) modeling system is being run for the 2002 calendar year on a 36/12 km grid for a 2002 base case and 2009 CAIR control case emission scenarios. The latest CMAQ simulations are the 2002 and 2009 BaseG2a base case emission scenarios. Details on the methodology for developing the ASIP modeling database are provided in Appendix A.

The ASIP 2002/2009 36/12 km CMAQ BaseG2a modeling database was used to assess the potential effects of restricting PRGS's emissions to its initial allocation would have on 8-hour ozone and PM<sub>2.5</sub> attainment. Two CMAQ 2009 12 km simulations were conducted:

2009 Purchasing: 2009 BaseG2a emissions with emissions for the PRGS assuming that they are satisfying their CAIR requirements with some level of emissions purchasing from other CAIR affected EGUs.

2009 No Purchasing: 2009 BaseG2a emissions with emissions for the PRGS assuming that PRGS meets the CAIR emissions allowances (EPA, 2005b,c) with no purchasing.

The results from the 2009 Purchasing and 2009 No Purchasing CMAQ simulations, along with the ASIP 2002 BaseG2a CMAQ results, were used to project 2009 PM<sub>2.5</sub> and 8-hour ozone Design Values following EPA guidance (EPA, 2007) to determine whether the proposed VDEQ rule to restrict the purchasing of emission allowances at the PRGS would have an effect on PM<sub>2.5</sub> or 8-hour ozone attainment in the region. The determination of the Design Values and a comparison of the measured and modeled values for relevant locations in Virginia, Maryland and the District of Columbia are presented in Section 2.0.

## **2.0 EFFECT OF VDEQ PROPOSED NO PURCHASING RULE ON 8-HOUR OZONE AND PM<sub>2.5</sub> ATTAINMENT**

The ASIP 2002/2009 36/12 km CMAQ BaseG2a modeling database was used to assess the potential effects the VDEQ No Purchasing emission allowances rule that would affect 8-hour ozone and PM<sub>2.5</sub> attainment through restricting the PRGS ability to purchase emission allowances. Two CMAQ 2009 12 km simulations were conducted:

2009 Purchasing: 2009 BaseG2a emissions with emissions modified for the PRGS assuming that it is satisfying their CAIR requirements with some level of purchasing of emission reductions from other CAIR affected EGUs to achieve its CAIR emission allowances.

2009 No Purchasing: 2009 BaseG2a emissions with emissions for the PRGS assuming that CAIR reductions are obtained at the PRGS so it is emitting at its CAIR emission allowance rates.

### **PRGS EMISSIONS SCENARIOS**

The 2009 EGU emissions for the ASIP BaseG2a modeling were generated starting with results from the Integrated Planning Model (IPM). IPM is a proprietary EGU emissions forecasting model that generates unit-specific EGU emissions given a set of constraints. For the RPO 2009 IPM CAIR run, constraints included which States fall under the ozone (NO<sub>x</sub> controls in ozone season) and/or PM<sub>2.5</sub> (year long NO<sub>x</sub> and SO<sub>2</sub> controls) components of CAIR, the CAIR emissions cap based on CAIR EGU SO<sub>2</sub> (EPA, 2005b) and NO<sub>x</sub> (EPA, 2005c) emission allowances and other information on each EGU. The IPM generated 2009 EGU emissions using a lowest cost solution that satisfied the CAIR cap and trade and other constraints. For many EGUs there were inconsistencies between the IPM 2009 EGU emission estimates under the CAIR cap and trade program and the plans of the operators and States. Consequently, for many EGUs the 2009 IPM EGU emissions were adjusted based on information from State and Local agencies to be more consistent with planned activities at the EGUs (MACTEC, 2007).

### **PRGS 2009 Purchasing and No Purchasing Scenarios**

For the 2009 Purchasing and 2009 No Purchasing emission scenarios, all emissions were identical to the ASIP 2009 BaseG2a base case emissions scenario except for emissions from the PRGS that were assumed to achieve the CAIR emission allowances allowing PRGS to purchase emissions from other sources (2009 Purchasing) or through PRGS required to achieve all CAIR emission reductions at the facility (2009 No Purchasing). Tables 2-1 and 2-2 list the SO<sub>2</sub> and NO<sub>x</sub> emissions for the PRGS 2009 Purchasing and 2009 No Purchasing emission scenarios. These emission rates were provided by Mirant. Table 2-3 summarizes and compares the total SO<sub>2</sub> and NO<sub>x</sub> emissions for the 2009 Purchasing and 2009 No Purchasing emission scenarios. The 2009 No Purchasing emissions correspond to the CAIR SO<sub>2</sub> and NO<sub>x</sub> emission allocations for the PRGS (EPA, 2005b,c). The 2009 PRGS NO<sub>x</sub> emissions under the 2009 No Purchasing scenario are estimated to be approximately half of what they would be under the 2009 Purchasing scenario. Whereas 2009 PRGS SO<sub>2</sub> emissions under the 2009 No Purchasing scenario would be approximately 28% lower than the 2009 Purchasing scenario.

**Table 2-1.** Assumed Mirant PRGS emissions for the 2009 Purchasing emission scenario.

| ORISID       | Point ID | NOx Emissions <sup>1</sup> |                    |                                 |              | SO2 Emissions <sup>2</sup> |                    |                                 |              |
|--------------|----------|----------------------------|--------------------|---------------------------------|--------------|----------------------------|--------------------|---------------------------------|--------------|
|              |          | lb/MBtu                    | Ozone Season (TPD) | Non-O <sub>3</sub> Season (TPD) | Annual (TPY) | lb/MBtu                    | Ozone Season (TPD) | Non-O <sub>3</sub> Season (TPD) | Annual (TPY) |
| 3788         | 1        | 0.33                       | 1.373              | 1.226                           | 470          | 0.60                       | 2.740              | 2.740                           | 1,000        |
| 3788         | 2        | 0.33                       | 1.373              | 1.226                           | 470          | 0.60                       | 2.740              | 2.740                           | 1,000        |
| 3788         | 3        | 0.26                       | 2.288              | 2.689                           | 920          | 0.60                       | 5.808              | 5.808                           | 2,120        |
| 3788         | 4        | 0.26                       | 2.288              | 2.689                           | 920          | 0.60                       | 5.808              | 5.808                           | 2,120        |
| 3788         | 5        | 0.26                       | 2.288              | 2.689                           | 920          | 0.60                       | 5.808              | 5.808                           | 2,120        |
| <b>Total</b> |          |                            |                    |                                 | <b>3,700</b> |                            |                    |                                 | <b>8,360</b> |

1. NOx emissions use ozone season typical day emissions for May 1 – September 30 and non-ozone season emissions for the rest of the year.
2. SO2 emissions use annual average emissions year round.

**Table 2-2.** Assumed Mirant PRGS emissions for the 2009 No Purchasing emission scenario.

| ORISID       | Point ID | NOx Emissions <sup>1</sup> |                    |                                 |              | SO2 Emissions <sup>2</sup> |                    |                                 |              |
|--------------|----------|----------------------------|--------------------|---------------------------------|--------------|----------------------------|--------------------|---------------------------------|--------------|
|              |          | lb/MBtu                    | Ozone Season (TPD) | Non-O <sub>3</sub> Season (TPD) | Annual (TPY) | lb/MBtu                    | Ozone Season (TPD) | Non-O <sub>3</sub> Season (TPD) | Annual (TPY) |
| 3788         | 1        | 0.119                      | 0.789              | 0.804                           | 291          | 0.42                       | 2.260              | 2.260                           | 825          |
| 3788         | 2        | 0.119                      | 0.719              | 0.733                           | 265          | 0.41                       | 2.299              | 2.299                           | 839          |
| 3788         | 3        | 0.119                      | 1.072              | 1.092                           | 396          | 0.47                       | 3.783              | 3.783                           | 1,381        |
| 3788         | 4        | 0.119                      | 1.092              | 1.112                           | 403          | 0.43                       | 4.170              | 4.170                           | 1,522        |
| 3788         | 5        | 0.119                      | 1.026              | 1.046                           | 379          | 0.43                       | 3.997              | 3.997                           | 1,459        |
| <b>Total</b> |          |                            |                    |                                 | <b>1,734</b> |                            |                    |                                 | <b>6,025</b> |

1. NOx emissions use ozone season typical day emissions for May 1 – September 30 and non-ozone season emissions for the rest of the year.
2. SO2 emissions use annual average emissions year round..

**Table 2-3.** Summary of total PRGS emissions for the 2009 Purchasing and 2009 No Purchasing emission scenarios.

| Scenario      | NOx Emissions   |                   | SO2 Emissions   |                   |
|---------------|-----------------|-------------------|-----------------|-------------------|
|               | Emissions (TPY) | Percent Reduction | Emissions (TPY) | Percent Reduction |
| Purchasing    | 3,700           | 0%                | 8,360           | 0%                |
| No Purchasing | 1,734           | -53%              | 6,025           | -28%              |

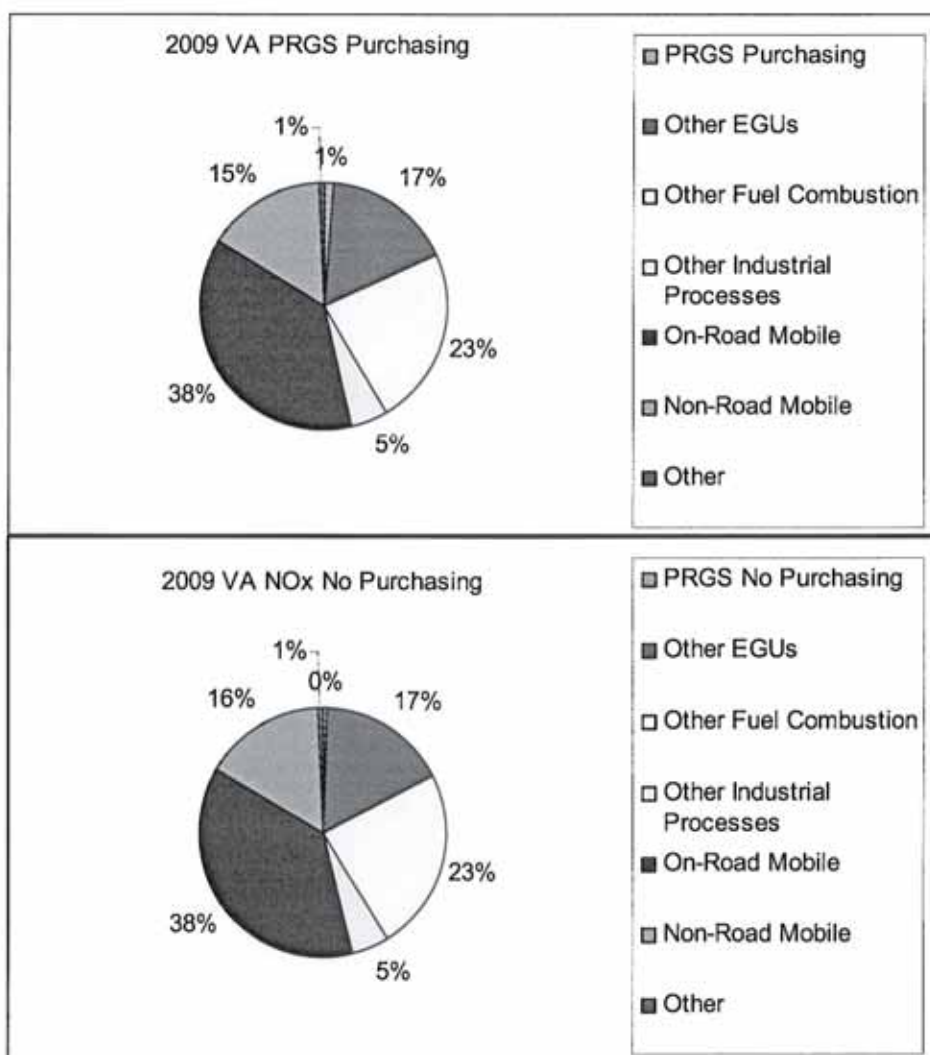
## PRGS PURCHASING AND NO PURCHASING MODELING RESULTS

Below we discuss the results from the 2009 PRGS Purchasing and 2009 No Purchasing CMAQ simulations and the effects on projected attainment of the 8-hour ozone and PM<sub>2.5</sub> NAAQS.

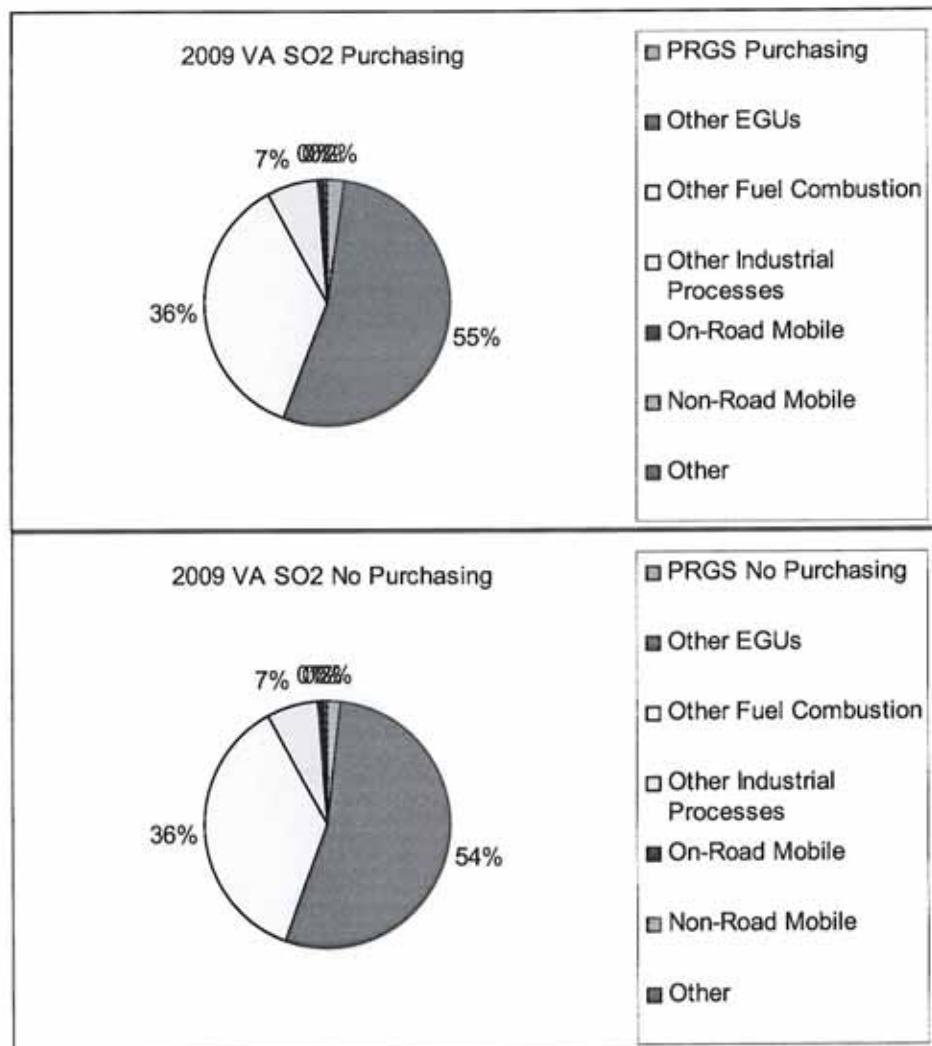
### Effects of Purchasing Restrictions on Virginia NO<sub>x</sub> and SO<sub>2</sub> Emissions

Figure 2-1 displays the sources of anthropogenic NO<sub>x</sub> and SO<sub>2</sub> emissions in Virginia by major source categories for the 2009 Purchasing and 2009 No Purchasing emissions scenario. ASIP 2009 Base G2a base case. In the 2009 Purchasing scenario, PRGS NO<sub>x</sub> emissions represent approximately 1.0% of the anthropogenic (Figure 2-1a). The PRGS contribution is reduced to approximately 0.5% under the 2009 No Purchasing scenario. Because the PRGS is a small portion of the Virginia anthropogenic NO<sub>x</sub> emissions inventory, the total amount of NO<sub>x</sub> emissions reduction in 2009 due to restricting the PRGS from purchasing emissions allowances is estimated to be 0.6%.

The PRGS SO<sub>2</sub> emissions under the 2009 Purchasing scenario are approximately 2.1% of the total anthropogenic SO<sub>2</sub> emissions in Virginia, similar numbers under the 2009 No Purchasing scenario is 1.6%. The effect of restricting PRGS from purchasing allowances to comply with CAIR would reduce anthropogenic emissions in Virginia by 0.6%.



**Figure 2-1a.** 2009 Virginia anthropogenic NO<sub>x</sub> emissions by major source category for the 2009 Purchasing (top) and 2009 No Purchasing (bottom) emission scenarios.



**Figure 2-1b.** 2009 Virginia anthropogenic SO<sub>2</sub> emissions by major source category for the 2009 Purchasing (top) and 2009 No Purchasing (bottom) emission scenarios.

### Effects of PRGS Purchasing Allowances on 8-Hour Ozone and PM<sub>2.5</sub> Attainment

Below we present the results of the modeling of the 2009 Purchasing and 2009 No Purchasing emissions scenarios on projected nonattainment. Whether an area is attaining or not attaining an air quality standard is defined by Design Values that are based on observed air quality concentrations. The 8-hour ozone Design Value for a monitoring site is defined as the three-year average of the fourth highest daily maximum 8-hour ozone concentrations in a year. If 8-hour ozone Design Values at all monitoring sites in an area are less than 85 ppb, then the area is attaining the 8-hour ozone National Ambient Air Quality Standard (NAAQS). If any one monitor has an 8-hour ozone Design Values of 85 ppb or greater, then the area may be declared as an ozone nonattainment area (NAA). The annual PM<sub>2.5</sub> Design Value at a monitor is defined as the three-year average of the annual average PM<sub>2.5</sub> concentration. An area may be declared nonattainment for PM<sub>2.5</sub> if any monitor in the area is 15.0 µg/m<sup>3</sup> or greater.

### Procedure for Projecting Future-Year 8-Hour Ozone and PM<sub>2.5</sub> Design Values

EPA guidance recommends specific procedures for using modeling results to project future-year attainment (EPA, 2007). For both projected 8-hour ozone and PM<sub>2.5</sub> attainment, EPA recommends using the modeling results in a relative fashion to scale the observed 8-hour ozone and PM<sub>2.5</sub> Design Values to obtain projected future-year Design Values for comparisons with the NAAQS in the attainment determination. The scaling factors are referred to as Relative Response Factors (RRFs) and are defined as the ratio of the future-year to current-year modeling results. The future-year projected Design Value (DVF) is obtained from the current-year observed baseline Design Value (DVB) at a monitoring site through the following equation:

$$DVF = DVB \times RRF$$

The EPA guidance approach for projecting 8-hour ozone and PM<sub>2.5</sub> Design Values has been implemented by ASIP for monitors in the southeastern U.S. and adjacent States and the same procedures were used in this study to project 2009 8-hour ozone and PM<sub>2.5</sub> Design Values for the 2009 Purchasing and 2009 No Purchasing CMAQ simulations.

EPA's recommended procedures for projecting 8-hour ozone Design Values and conducting the modeled attainment test are as follows (see pg 41 of EPA, 2007):

**Step 1. Compute Baseline Design Values (DVB):** Compute the site-specific baseline design values (DVBs) from observed 8-hour ozone monitoring data by using the average of three-years of 8-hour ozone design Values that include the baseline inventory year. For the ASIP database, the baseline inventory year and modeling year is 2002. Therefore, the site-specific DVBs would be based on the three year average of 8-hour ozone Design Values for years ending in 2002, 2003 and 2004. Recall that an 8-hour ozone Design Value is the three year average of the fourth highest daily maximum 8-hour ozone concentration. Thus, the DVB weights the fourth highest daily maximum 8-hour ozone concentrations from the 5-year period of 2000-2004 by factors of 1, 2, 3, 2 and 1, respectively.

**Step 2. Estimate Relative Response Factors (RRFs):** Use air quality modeling results to estimate a RRF for each monitoring site i:

$$RRF_i = (\text{mean 8-hour daily max})_{\text{future}} / (\text{mean 8-hour daily max})_{\text{baseline}}$$

For each monitoring site and day, the highest daily maximum 8-hour ozone monitoring site near the monitor is used in the RRF calculation. By "near the monitor," EPA suggests within 15 km, which is a 3 x 3 array of cells centered on the monitor for the ASIP 12 km modeling database. EPA recommends that RRFs be based on only days when high modeled baseline daily maximum 8-hour ozone concentrations occur so recommends to use only days when the modeled baseline value is equal to or higher than an 85 ppb threshold. EPA also recommends that at least 10 modeling days should be used in the RRF calculation, so allows a lowering of the 85 ppb threshold to achieve the 10 modeling days with a floor of 70 ppb.

Step 3. Calculate the future Design Values (DVF) using the baseline Design Values (DVB) from Step 1 and RRFs from Step 2: EPA recommends using RRFs with 3 significant values to the right of the decimal point. When the RRF is applied to the DVB to obtain the DVF in parts per billion (ppb), the projected DVF value is then truncated for comparison with the NAAQS and WOE range.

EPA's 8-hour ozone modeled attainment test is not a bright line comparisons against the NAAQS, rather EPA recommends that if future-year DVFs are close to the standard then a detailed Weight of Evidence (WOE) analysis should be conducted (EPA, 2007). For 8-hour ozone, if there are DVFs in a NAA that lie between 82-87 ppb then a detailed WOE analysis should be conducted. If there are any DVFs in a NAA that are > 87 ppb, then EPA argues no amount of WOE analysis would like to be convincing that attainment would be achieved. On the other hand, if all DVFs in a NAA are < 82 ppb, then the modeled attainment test would be fairly convincing, although EPA still maintains that a WOE analysis would be beneficial.

For projecting PM<sub>2.5</sub> Design Values, EPA recommends a similar procedure as described above, only it is performed for each major component of PM<sub>2.5</sub>. This procedure is called the Speciated Modeled Attainment Test (SMAT) and uses PM<sub>2.5</sub> Design Values based on observed PM<sub>2.5</sub> concentrations from the Federal Reference Method (FRM) monitors and speciated PM<sub>2.5</sub> concentrations from the Speciated Trends Network (STN) and IMPROVE monitoring sites. The SMAT is applied to quarterly averaged Design Values and averaged to obtain the annual average values for comparison with the PM<sub>2.5</sub> NAAQS and WOE range. EPA guidance notes that if there are any projected PM<sub>2.5</sub> DVFs in the NAA that are in the 14.5-15.5 µg/m<sup>3</sup> range, then a detailed WOE analysis would be needed.

#### Projected 8-Hour Ozone Design Values for the 2009 Purchasing and 2009 No Purchasing Scenarios

Using the procedures described above, the 2000-2004 baseline Design Values (DVBs) in the eastern U.S. were projected to 2009 under the PRGS Purchasing and 2009 No Purchasing emission scenarios. Table 2-4 displays the projected 8-hour ozone Design Values (DVFs) in Virginia, Maryland and Washington D.C. under the 2009 Purchasing and 2009 No Purchasing emission scenarios. EPA guidance recommends truncating the final DVFs to the nearest ppb. However, since the changes to the projected DVFs between the 2009 Purchasing and 2009 No Purchasing scenarios are so small, we present them to the nearest tenth of a ppb in Table 2-4. The differences between the DVFs between the 2009 Purchasing and 2009 No Purchasing emissions scenarios range from 0.0 to 0.3 ppb. Attainment of the 8-hour ozone NAAQS is based on measured ozone values that are reported to the EPA AIRS database to the nearest ppb. Since the changes in projected DVFs range between 0.0 and 0.3 ppb then the differences between the projected DVFs between the 2009 Purchasing and 2009 No Purchasing are below the precision of the ozone measurements. Therefore, the restrictions on allowing PRGS to purchase emission allowances to comply with CAIR would have no measurable effect on 8-hour ozone attainment.

**Table 2-4.** Projected 2009 8-hour ozone Design Values in Virginia, Maryland and Washington D.C. for the PRGS 2009 Purchasing and 2009 No Purchasing emissions scenarios.

| State | County-Site ID            | Observed<br>2000-2004<br>DVBase<br>(ppb) | Projected<br>DVF 2009<br>No<br>Purchasing<br>(ppb) <sup>1</sup> | Projected<br>DVF 2009<br>Purchasing<br>(ppb) <sup>1</sup> | Difference<br>Purchasing<br>minus No<br>Purchasing<br>(ppb) |
|-------|---------------------------|--|---|---|---|
| DC    | District of Columbia-0025 | 88.7                                     | 78.9  | 79.2  | 0.3   |
| DC    | District of Columbia-0041 | 89.0                                     | 80.2  | 80.5  | 0.3   |
| DC    | District of Columbia-0043 | 92.7                                     | 83.5  | 83.8  | 0.3   |
| MD    | Anne Arundel-0014         | 98.0                                     | 87.7  | 87.9  | 0.2   |
| MD    | Anne Arundel-0019         | 97.0                                     | 86.0  | 86.1  | 0.1   |
| MD    | Charles-0010              | 93.3                                     | 78.3  | 78.6  | 0.3   |
| MD    | Frederick-0037            | 87.3                                     | 75.3  | 75.3  | 0.0   |
| MD    | Montgomery-3001           | 87.0                                     | 76.2  | 76.4  | 0.2   |
| MD    | Prince George's-0002      | 94.0                                     | 82.6  | 82.9  | 0.3   |
| MD    | Prince George's-8003      | 94.0                                     | 82.0  | 82.3  | 0.3   |
| MD    | Washington-0009           | 83.0                                     | 72.5  | 72.5  | 0.3   |
| VA    | Arlington-0020            | 96.7                                     | 66.5  | 66.5  | 0.0   |
| VA    | Caroline-0001             | 82.3                                     | 75.6  | 75.6  | 0.0   |
| VA    | Charles City-0002         | 89.3                                     | 74.4  | 74.4  | 0.0   |
| VA    | Chesterfield-0004         | 84.7                                     | 71.6  | 71.6  | 0.0   |
| VA    | Fairfax-0005              | 87.0                                     | 75.4  | 75.4  | 0.0   |
| VA    | Fairfax-0018              | 96.7                                     | 67.9  | 67.9  | 0.0   |
| VA    | Fairfax-0030              | 95.0                                     | 64.1  | 64.1  | 0.0   |
| VA    | Fairfax-1005              | 94.0                                     | 75.7  | 75.7  | 0.0   |
| VA    | Fairfax-5001              | 88.0                                     | 70.3  | 70.3  | 0.0   |
| VA    | Fauquier-0002             | 79.3                                     | 62.7  | 62.7  | 0.0   |
| VA    | Frederick-0010            | 82.7                                     | 69.3  | 69.3  | 0.0   |
| VA    | Hanover-0003              | 92.0                                     | 66.0  | 66.0  | 0.0   |
| VA    | Henrico-0014              | 88.3                                     | 62.4  | 62.4  | 0.0   |
| VA    | Loudoun-1005              | 90.0                                     | 87.1  | 87.4  | 0.3   |
| VA    | Madison-0003              | 84.7                                     | 71.3  | 71.4  | 0.1   |
| VA    | Page-0004                 | 79.7                                     | 78.9  | 78.9  | 0.0   |
| VA    | Prince William-0009       | 85.0                                     | 75.3  | 75.3  | 0.0   |
| VA    | Roanoke-1004              | 83.7                                     | 75.8  | 75.9  | 0.1   |
| VA    | Rockbridge-0003           | 76.7                                     | 86.4  | 86.6  | 0.2   |
| VA    | Stafford-0001             | 86.0                                     | 84.8  | 85.1  | 0.3   |
| VA    | Wythe-0002                | 79.7                                     | 83.5  | 83.7  | 0.2   |
| VA    | Alexandria-0009           | 90.0                                     | 78.8  | 79.0  | 0.2   |
| VA    | Hampton-0004              | 88.3                                     | 68.6  | 68.7  | 0.1   |
| VA    | Suffolk-0004              | 87.0                                     | 72.5  | 72.5  | 0.0   |
| VA    | Suffolk-0005              | 82.3                                     | 81.3  | 81.3  | 0.0   |

<sup>1</sup> EPA guidance recommends truncating the final DVF to the nearest ppb (EPA, 2007), results presented here to the nearest tenth of a ppb in order to see differences between 2009 Purchasing and 2009 No Purchasing projected 2009 DVFs.

### Projected PM<sub>2.5</sub> Design Values for the 2009 Purchasing and 2009 No Purchasing Scenarios

Table 2-5 displays the projected PM<sub>2.5</sub> Design Values for the 2009 Purchasing and 2009 No Purchasing emission scenarios. The projected PM<sub>2.5</sub> Design Values for the PRGS Purchasing and No Purchasing scenarios are identical for 23 of the 24 monitoring sites. At the one site where they are different (24-003-0014 in Anne Arundel, Maryland), the 2009 projected PM<sub>2.5</sub> Design Value for the PRGS Purchasing scenario (10.0 µg/m<sup>3</sup>) is 0.1 µg/m<sup>3</sup> higher than the No Purchasing scenario (9.9 µg/m<sup>3</sup>) and both are well below the PM<sub>2.5</sub> NAAQS of 15.0 µg/m<sup>3</sup>. The maximum 2009 projected PM<sub>2.5</sub> Design Value is 12.5 µg/m<sup>3</sup> (site 51-520-0006 in Bristol, Virginia), which is also well below the PM<sub>2.5</sub> NAAQS, and is exactly the same for the two 2009 emission scenarios. This value is also well below the 14.5-15.5 µg/m<sup>3</sup> range where a detailed WOE analysis is needed in an attainment demonstration. Thus, restricting PRGS from purchasing emission allowances to comply with CAIR would have no effect on PM<sub>2.5</sub> attainment.

**Table 2-5.** Projected 2009 PM<sub>2.5</sub> Design Values in Virginia and Maryland for the PRGS 2009 Purchasing and 2009 No Purchasing emissions scenarios.

| AIRS ID     | State | County         | Observed                 | 2009                     | 2009                     | Differences                |
|-------------|-------|----------------|--------------------------|--------------------------|--------------------------|----------------------------|
|             |       |                | 2000-2004                | No Purchasing            | Purchasing               | Purchasing – No Purchasing |
|             |       |                | DVB (µg/m <sup>3</sup> ) | DVF (µg/m <sup>3</sup> ) | DVF (µg/m <sup>3</sup> ) | (µg/m <sup>3</sup> )       |
| 24-003-0014 | MD    | Anne Arundel   | 12.3                     | 9.9                      | 10.0                     | 0.1                        |
| 24-003-0019 | MD    | Anne Arundel   | 13.2                     | 10.6                     | 10.6                     | 0.0                        |
| 24-003-1003 | MD    | Anne Arundel   | 15.4                     | 12.6                     | 12.6                     | 0.0                        |
| 24-003-2002 | MD    | Anne Arundel   | 14.4                     | 11.8                     | 11.8                     | 0.0                        |
| 24-031-3001 | MD    | Montgomery     | 12.8                     | 10.4                     | 10.4                     | 0.0                        |
| 24-043-0009 | MD    | Washington     | 14.4                     | 11.8                     | 11.8                     | 0.0                        |
| 51-013-0020 | VA    | Arlington      | 14.6                     | 12.0                     | 12.0                     | 0.0                        |
| 51-036-0002 | VA    | Charles City   | 12.8                     | 10.7                     | 10.7                     | 0.0                        |
| 51-041-0003 | VA    | Chesterfield   | 13.7                     | 11.6                     | 11.6                     | 0.0                        |
| 51-059-0030 | VA    | Fairfax        | 13.6                     | 11.0                     | 11.0                     | 0.0                        |
| 51-059-5001 | VA    | Fairfax        | 14.2                     | 11.6                     | 11.6                     | 0.0                        |
| 51-087-0014 | VA    | Henrico        | 13.8                     | 11.6                     | 11.6                     | 0.0                        |
| 51-087-0015 | VA    | Henrico        | 13.0                     | 10.9                     | 10.9                     | 0.0                        |
| 51-107-1005 | VA    | Loudoun        | 13.6                     | 11.1                     | 11.1                     | 0.0                        |
| 51-139-0004 | VA    | Page           | 13.0                     | 10.7                     | 10.7                     | 0.0                        |
| 51-520-0006 | VA    | Bristol        | 14.5                     | 12.5                     | 12.5                     | 0.0                        |
| 51-550-0012 | VA    | Chesapeake     | 12.5                     | 10.7                     | 10.7                     | 0.0                        |
| 51-650-0004 | VA    | Hampton        | 12.2                     | 10.3                     | 10.3                     | 0.0                        |
| 51-700-0013 | VA    | Newport News   | 12.0                     | 10.2                     | 10.2                     | 0.0                        |
| 51-710-0024 | VA    | Norfolk        | 13.0                     | 11.1                     | 11.1                     | 0.0                        |
| 51-760-0020 | VA    | Richmond       | 14.1                     | 11.8                     | 11.8                     | 0.0                        |
| 51-770-0014 | VA    | Roanoke        | 14.4                     | 11.9                     | 11.9                     | 0.0                        |
| 51-775-0010 | VA    | Salem          | 14.8                     | 12.4                     | 12.4                     | 0.0                        |
| 51-810-0008 | VA    | Virginia Beach | 12.6                     | 10.7                     | 10.7                     | 0.0                        |

### 3.0 ANALYSIS OF THE 2009 PURCHASING AND NO PURCHASING RESULTS

The modeling of the effects of 2009 Purchasing and No Purchasing emission scenarios used the ASIP 2002 36/12 km CMAQ modeling database. This database was developed to analyze the effects of emissions changes from 2002 to 2009 and 2018 on ozone, PM<sub>2.5</sub> and regional haze. However, in the analysis of the VDEQ No Purchasing Rule we are looking at changes in SO<sub>2</sub> and NO<sub>x</sub> emissions at a single facility, the Potomac River Generating Station (PRGS). Emissions from the PRGS are emitted out of 5 stacks that form plumes. The chemistry in these plumes is very different than the surrounding air due to the elevated concentrations of SO<sub>2</sub> and, especially, NO<sub>x</sub> in the plume. However, the Purchasing/No Purchasing modeling simulated these impacts using a 12 km grid which results in the instantaneous dilution of the PRGS SO<sub>2</sub> and NO<sub>x</sub> emissions across a 12 km by 12 km grid cell. As discussed below, this modeling algorithm will overstate the formation rate of ozone and secondary particulate matter (PM) from the PRGS emissions so that the calculated ozone and PM<sub>2.5</sub> impacts presented in Section 3 and at the end of this section are overstated or conservative, i.e. the modeled values are higher than would actually occur. The reasons why the ozone and PM<sub>2.5</sub> impacts due to emissions from the PRGS are overstated are discussed below.

### OZONE AND SULFATE FORMATION OF POINT SOURCE PLUMES

In order to understand why the treatment of emissions from the PRGS using a 12 km grid overstates the downwind ozone and secondary PM<sub>2.5</sub> impacts we need to understand the chemistry of ozone and secondary PM formation in point source plumes, like those from the Potomac River Generating Station (PRGS) electrical generating unit (EGU).

#### Ozone and Secondary PM Formation within Point Source Plumes

The chemistry within point source plumes, such as plumes from the PRGS, is very different from that in the surrounding air. Within the plumes close to the source there are higher NO<sub>x</sub> concentrations that inhibit ozone and secondary PM formation in the plume. Understanding and accounting for this chemistry is important when modeling point source plumes.

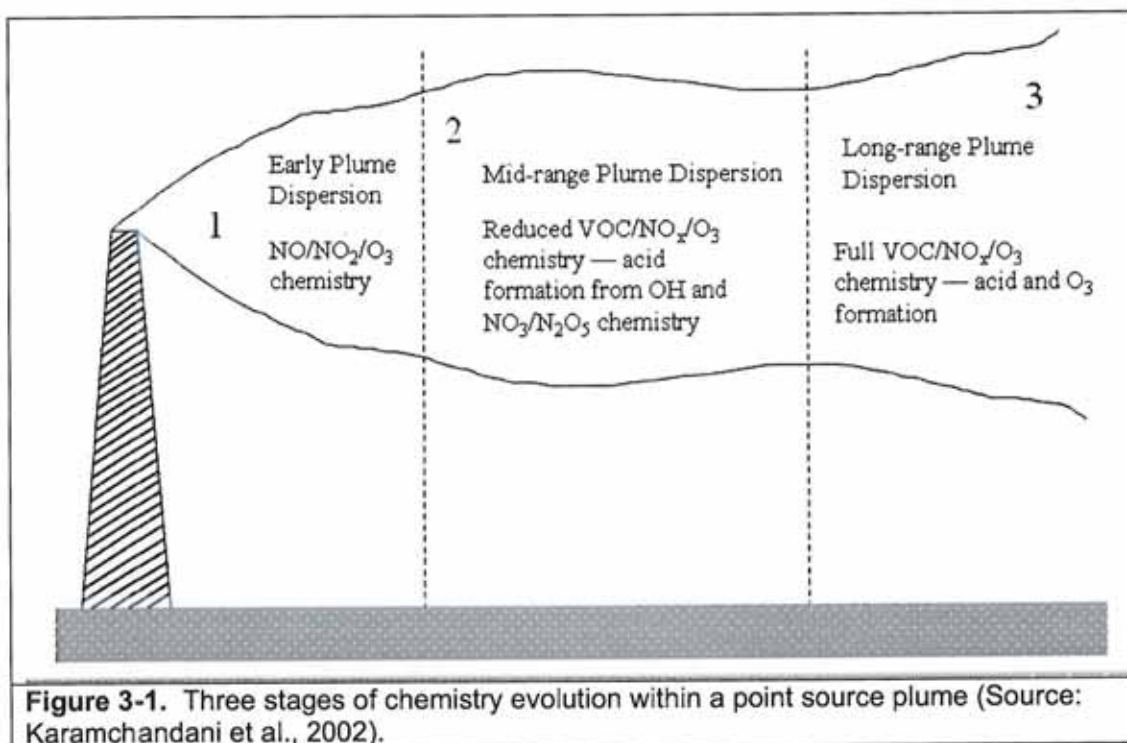
This unique chemistry has been characterized by the scientific community by describing three stages of chemical evolution within a point source plume that are shown schematically in Figure 3-1. The chemical evolution of NO<sub>x</sub> point source plumes is well documented in the atmospheric chemistry literature (e.g., Seinfeld and Pandis, 1998).

**Stage 1 – Early Plume Dispersion:** Near the source, the point source plume chemistry is dominated by the comparatively high NO<sub>x</sub> (=NO+NO<sub>2</sub>) concentrations that completely eliminate (scavenge) any ozone present in the atmosphere ( $\text{NO} + \text{O}_3 \rightarrow \text{NO}_2 + \text{O}_2$ ). As a result, with the possible exception of a little nitric acid formation, no formation of secondary species, such as ozone and sulfate, occurs. Chemistry is dominated by inorganic reactions involving NO/NO<sub>2</sub>/O<sub>3</sub>, and there are essentially no organic reactions involving Volatile Organic Compounds (VOCs) since, for the most part, VOCs are not present in power plant emissions. Consequently there is very little, if any, ozone or secondary sulfate or nitrate formed in the plume near the source. The Stage 1 plume chemistry may occur for just a few km or may occur

many 10s to 100s of km downwind if the emissions are emitted in a highly stable atmosphere (e.g., aloft above the mixing height or at night).

**Stage 2 – Mid-Range Plume Dispersion:** As the plume expands, it may entrain background VOC concentrations (e.g., from biogenic sources), so that some reduced photochemistry may start to occur. However, the continued high  $\text{NO}_x$  concentrations in the plume will inhibit photochemistry and ozone and sulfate formation. Instead, any “radicals” generated (e.g.,  $\text{OH}$ )<sup>1</sup> that are needed for ozone and sulfate formation will react with the high  $\text{NO}_2$  concentrations to produce nitric acid, not ozone or sulfate. Although no ozone formation occurs in the center of the plume, ozone formation may start to occur on the edges of the plume where  $\text{NO}_x$  concentrations are lower. Stage 2 chemistry may last 10s to 100s km downwind from the source depending on atmospheric conditions.

**Stage 3 – Long Range Plume Dispersion:** At far downwind distances the plume expands, so that the  $\text{NO}_x$  in the plume becomes diluted to the point where photochemistry may occur if background VOCs and sunlight are present. It is in Stage 3 plume chemistry that a vast majority of ozone and secondary PM (sulfate and nitrate) formation occurs in plumes.



**Figure 3-1.** Three stages of chemistry evolution within a point source plume (Source: Karamchandani et al., 2002).

<sup>1</sup> Radicals are molecules or atoms that have a single “unpaired” electron and include transient species of atoms, molecules or ions in the gas phase. They are typically highly reactive and the main oxidizing agent that forms ozone and converts  $\text{SO}_2$  to sulfate and  $\text{NO}_x$  to nitrate.

## Observational and Theoretical Verification of Reduced Ozone and Secondary PM Formation in Point Source Plumes

The chemical processes that inhibit ozone and secondary PM formation in NO<sub>x</sub> point source plumes are well understood and have been documented in real-world atmospheric measurements. Miller and co-workers (1978) published results in the December 1978 issue of *Science* that documented, through aircraft measurements and chemistry models, the near-source (Stage 1) depletion of ozone within a coal-fired power plant plume (Oak Creek in Wisconsin) as well as ozone enhancements ("bulges") further downwind (Stage 3). Aircraft measurements were made across the power plant plume 300 m above the surface of Lake Michigan and modeling was performed to simulate the measurements.

Ryerson and co-workers (2001) published a paper in *Science* that examined aircraft measurements downwind of three power plants in the eastern U.S. They found that ozone formation per molecule NO<sub>x</sub> emitted depended on the amount of NO<sub>x</sub> emissions, background VOC and atmospheric conditions. The near-source depletion of ozone was observed in all three power plant plumes, but the transition from Stage 1 to Stage 2 and Stage 3 was much faster in the lower NO<sub>x</sub> emission power plants, and the lower NO<sub>x</sub> emissions power plants produced much more ozone per molecule NO<sub>x</sub> emitted than the higher NO<sub>x</sub> emissions power plant. For example, the authors note that a factor of 8 reduction (~90%) in NO<sub>x</sub> emissions from the high NO<sub>x</sub> emitting Cumberland EGU (13.9 tons/hour) would result in only a factor of 2.3 reduction (~60%) in net ozone production because of the more efficient ozone formation under the lower NO<sub>x</sub> conditions. The same photochemical processes that form ozone also produce secondary PM.

Gillani and Pleim (1996) performed a modeling analysis and concluded that PGMs that use coarse grid resolution (e.g., 12 and 36 km) unduly distort plume chemistry and overstate ozone and other secondary species formation rates. Their opinion is that *"regional model accuracy would be significantly improved by limiting regional grid size to 20-30 km, by using finer nested grids (~1-4 km) in metropolitan sub-domains, and by detailed plume-in-grid treatment of major point sources"* (Gillani and Pleim, 1996).

## Coarse Grid Resolution Overstates Ozone and Secondary PM Impacts from the PRGS

Use of coarse grid resolution (i.e., 12 km) leads to an overstatement of the near-source ozone and secondary PM formation due to emissions from the PRGS. This approach effectively skips Stages I and II of the chemical evolution of plumes described above (when ozone and secondary PM formation is inhibited). By dispersing the plume directly into a 12 km grid, emissions from the PRGS enter directly with the Stage 3 chemistry resulting in an overstatement of ozone and secondary PM formation.

## EFFECTS OF THE PRGS PURCHASING ON MODEL ESTIMATED 8-HOUR OZONE AND PM<sub>2.5</sub> CONCENTRATIONS

The differences in the spatial distribution of the CMAQ-estimated daily maximum 8-hour ozone concentrations between the 2009 Purchasing and 2009 No Purchasing emission scenario were examined for the four days with the highest estimated 8-hour ozone concentration in the region. Allowing PRGS to purchase emission allowances to comply with the CAIR requirements is

estimated to have a very small highly localized increase (typically of about 1 ppb) near the source, with immeasurable reductions in ozone away from the source. As noted in the discussion above, near the source the PRGS ozone impacts are overstated due to initial over dilution of the PRGS NO<sub>x</sub> emissions. Thus, in reality the emission reductions associated with not allowing PRGS to purchase emission allowances would likely have no measurable impact throughout the region.

The differences in the CMAQ-estimated annual average PM<sub>2.5</sub> concentrations between the 2009 Purchasing and 2009 No Purchasing emission scenarios were extremely small. The maximum increase in annual PM<sub>2.5</sub> concentration due to allowing PRGS to purchase emission allowances to comply with CAIR is 0.03 µg/m<sup>3</sup>, an extremely small number. Annual PM<sub>2.5</sub> concentrations are typically reported to the nearest tenth of a µg/m<sup>3</sup>, thus these increase can not be considered significant.

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## **APPENDIX A**

### **Description of the ASIP 8-Hour and PM<sub>2.5</sub> Attainment Demonstration Modeling Database**

## OVERVIEW OF ASIP MODELING APPROACH

The Association for Southeastern Integrated Planning (ASIP) is using the CMAQ modeling system for the 2002 calendar year to project 2009 PM<sub>2.5</sub> and 8-hour ozone Design Values in the southeastern States to determine whether attainment is achieved. At the outset of the ASIP modeling, a Modeling Protocol (Morris et al., 2006a) and Quality Assurance Project Plan (QAPP; Morris and Stella, 2005) was prepared to provide details of the modeling approach and delineate quality assurance and quality control (QA/QC) procedures that will be employed and to build consensus among the States, Stakeholders and other interested groups involved in the study. The ASIP modeling is closely linked and overlaps with the modeling being performed by the Visibility Improvement State and Tribal Association of the Southeast (VISTAS; ENVIRON, AG and UCR, 2004). ASIP and VISTAS share a common 2002 36/12 km CMAQ modeling database and 2002 base case CMAQ simulations. The difference is that ASIP is modeling the 2009 future-year for the purposes of demonstrating attainment of the PM<sub>2.5</sub> and 8-hour ozone National Ambient Air Quality Standards (NAAQS) in NAAs, whereas VISTAS is modeling the 2018 future-year to demonstrate reasonable progress toward achieving natural visibility conditions at Class I areas as part of the Regional Haze Rule (RHR). Below we describe the modeling approach used by ASIP to project 8-hour ozone and PM<sub>2.5</sub> attainment in the southeastern States, more details are provided in the Modeling Protocol and QAPP.

### Models Used

Based on the findings of the extensive sensitivity testing and model evaluation conducted in the VISTAS Phase I and II modeling activities (e.g., Morris et al., 2004a,b), ASIP selected the following models for use in modeling 8-hour ozone and particulate matter (PM) of size of 2.5 microns or less (PM<sub>2.5</sub>):

- **MM5:** The Pennsylvania State University/National Center for Atmospheric Research (PSU/NCAR) Mesoscale Meteorological Model (MM5) is a nonhydrostatic, prognostic meteorological model routinely used for urban- and regional-scale photochemical, fine particulate and regional haze regulatory modeling studies (Anthes and Warner, 1978; Dudhia, 1993).
- **SMOKE:** The Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system is an emissions modeling system that generates hourly gridded speciated emission inputs of mobile, nonroad, area, point, fire and biogenic emission sources for photochemical grid models (Coats and Houyoux, 1996; Houyoux and Vukovich, 1999).
- **CMAQ:** EPA's Models-3/Community Multiscale Air Quality (CMAQ) modeling system is a 'One-Atmosphere' photochemical grid model capable of addressing ozone, particulate matter (PM), visibility and acid deposition at regional scale for periods up to one year (Byun and Ching, 1999).

Application of the MM5 for the 2002 annual period and the ASIP 36/12 km domains was performed by Baron Advanced Meteorological Systems (BAMS) under contract to SESARM as part of the VISTAS Phase II activities (Olerud, 2003a,b). Details of the model application and evaluation procedures being carried out by BAMS may be found at <http://www.baronams.com/projects/VISTAS/>.

SMOKE version 2.3 is being used for the ASIP/VISTAS emissions modeling. The SMOKE modeling system and documentation are available from the CMAS Center ([www.cmascenter.org](http://www.cmascenter.org)). Details on the SMOKE emissions modeling can be found in the Modeling Protocol (Morris et al., 2006a).

CMAQ Version 4.5.1 with an enhancement to the Secondary Organic Aerosol (SOA) module is being used for the ASIP/VISTAS modeling (CMAQ SOAmods). Early testing of the standard CMAQ model found it under-predicted organic mass carbon (OMC), especially in the summer months. A review of the CMAQ treatment of OMC found that it neglected several now known processes that lead to SOA formation. Thus, CMAQ SOA module was enhanced to include the following processes not accounted for in the standard version of the model: SOA from isoprene; SOA from sesquiterpene and the polymerization of SOA so that it is no longer volatile. The new CMAQ SOAmods was able to replicate the observed OMC concentrations much better than the standard version and was adopted by ASIP and VISTAS (Morris et al., 2006b).

### Horizontal Modeling Domain

The ASIP horizontal domain for each of the models was identical to those used in the VISTAS modeling. As in VISTAS, as well as the CENRAP and WRAP RPOs, a coarse grid continental United States (US) domain with a 36 km horizontal grid resolution was used (the Inter-RPO domain). The CMAQ domain is nested in the MM5 domain. The selection of the MM5 domain is described in the VISTAS MM5 modeling documents (e.g., Olerud, 2003a,b). Figure A-1 displays the MM5 horizontal domain as the outer most, blue grid. Also shown in Figure A-1 is the CMAQ 36 km domain nested in the MM5 domain. To achieve finer spatial resolution in the eastern U.S. a nested high resolution grid with a 12 km grid resolution is used. Figure A-2 shows the 36 km CMAQ continental grid and the high resolution, nested 12-km grid in the eastern U.S. Figure A-3 shows in more detail the 12 km grid for the eastern U.S. region that is the focus of ASIP.

Both MM5 and CMAQ employ the Regional Planning Organization (RPO) unified grid definition for the 36 km continental domain. The RPO unified grid consists of a Lambert-Conformal map projection using the map projections parameters listed in Table A-1.

**Table A-1.** RPO Unified Grid Definition.

| PARAMETER  | VALUE             |
|------------|-------------------|
| projection | Lambert-conformal |
| alpha      | 33 degrees        |
| beta       | 45 degrees        |
| x center   | 97 degrees        |
| y center   | 40 degrees        |

The MM5 36 km grid includes 164 cells in the east-west dimension and by 128 cells in the north-south dimension. The CMAQ 36 km grid includes 148 cells in the east-west dimension and 112 cells in the north-south dimension. Because the MM5 model is also nested in the Eta model, there is a possibility of boundary effects near the MM5 boundary that occur as the Eta meteorological variables are being simulated by MM5 and must come into dynamic balance with MM5's algorithms. Thus, a larger MM5 domain was selected to provide a buffer of 8 to 9 grid cells around each boundary of the CMAQ 36 km domain. The buffer region used here exceeds the EPA suggestion of at least 5 grid cell buffers at each boundary.

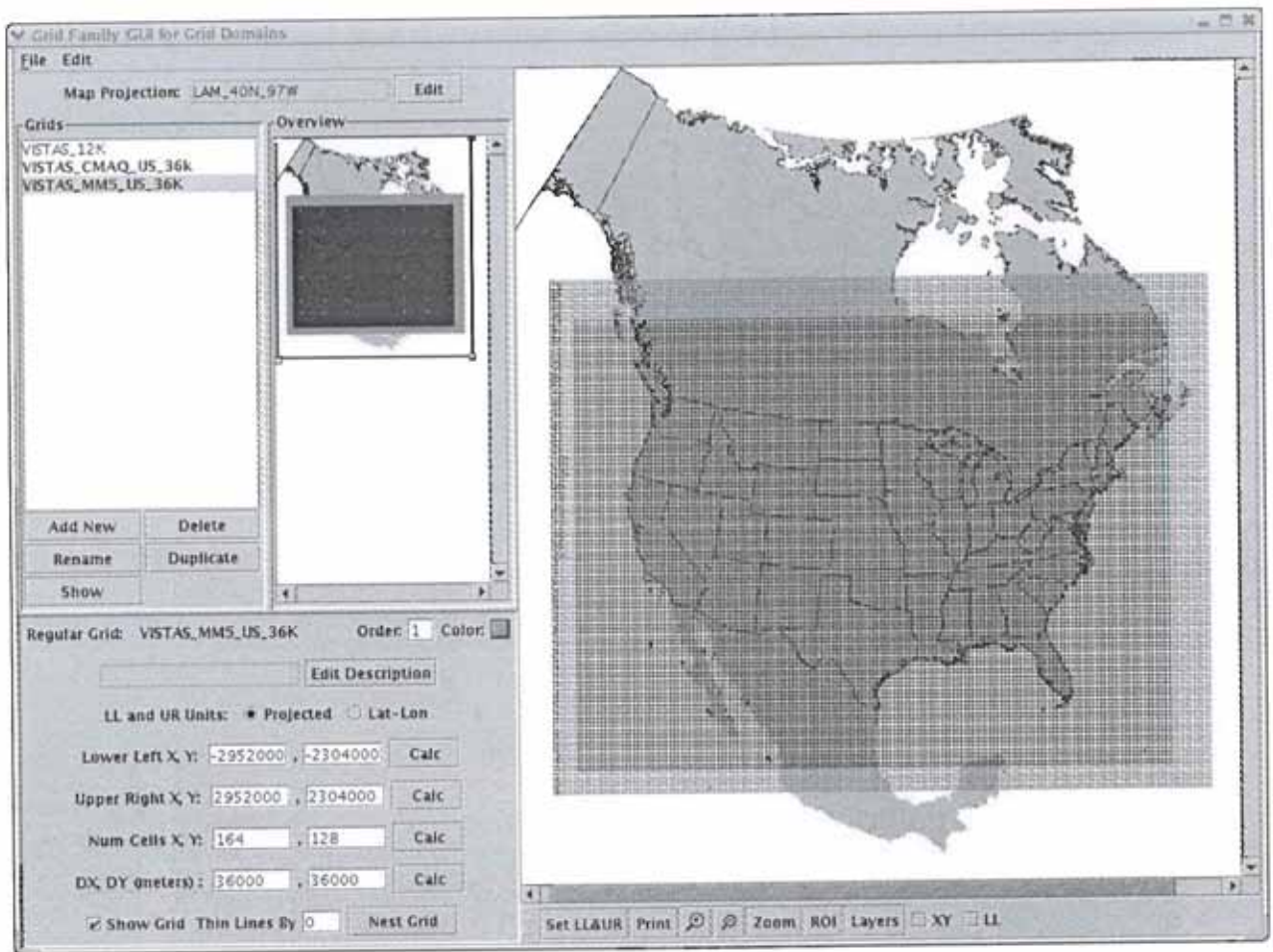
Table A-2 lists the number of rows and columns and the definition of the X and Y origin (i.e., the southwest corner) for the 36 km and 12 km grids for both MM5 and CMAQ. Note that the CMAQ grid is rotated 90 degrees relative to the MM5 grid, so rows and columns are reversed. In Table 4-2 "Dot" refers to the grid mesh defined at the vertices of the grid cells while "cross" refers to the grid mesh defined by the grid cell centers. Thus, the dimension of the dot mesh is equal to the cross mesh plus one.

**Table A-2.** Grid Definitions for MM5 and CMAQ.

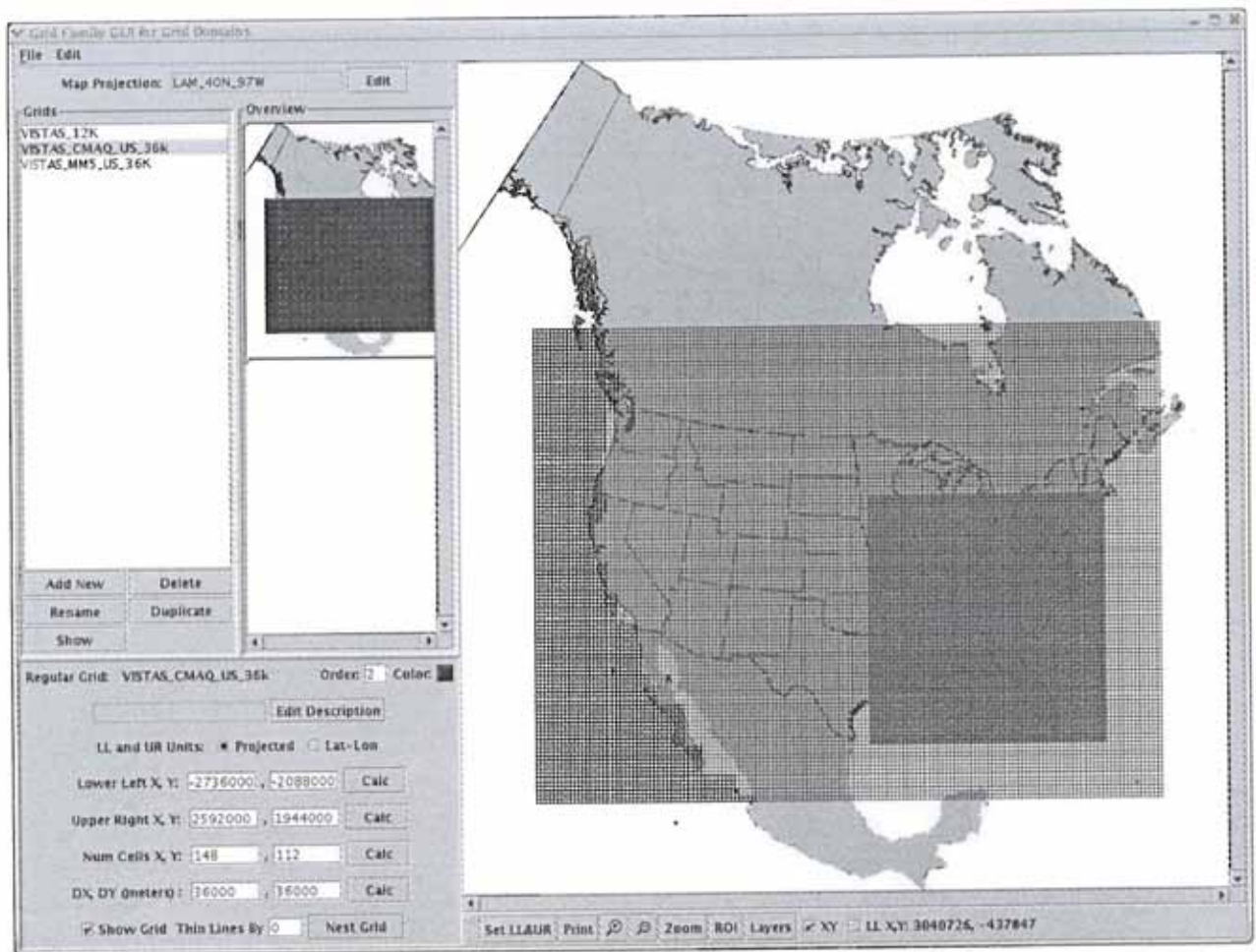
| MODEL     | COLUMNS<br>DOT(CROSS) | ROWS<br>DOT(CROSS) | XORIGIN  | YORIGIN  |
|-----------|-----------------------|--------------------|----------|----------|
| MM5 36km  | 129 (128)             | 165 (164)          | -2952000 | -2304000 |
| CMAQ 36km | 149 (148)             | 113 (112)          | -2736000 | -2088000 |
| MM5 12km  | 190 (189)             | 181 (180)          | 7200     | -1656000 |
| CMAQ 12km | 169 (168)             | 178 (177)          | 108000   | -1620000 |

## Vertical Modeling Domain

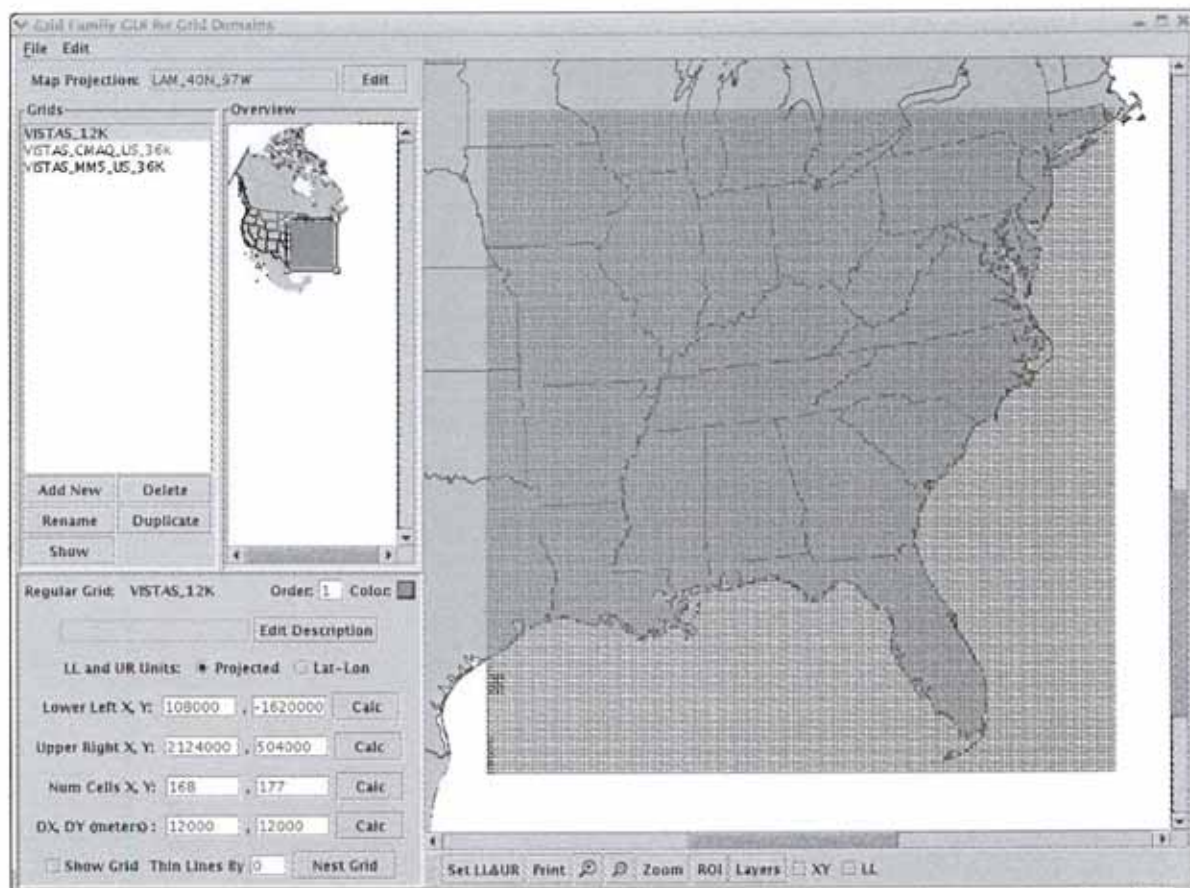
The CMAQ vertical structure is primarily defined by the vertical grid used in the MM5 modeling. The MM5 model employed a terrain following coordinate system defined by pressure levels, using 34 layers that extend from the surface to the 100 mb. Table A-3 lists the layer definitions for both MM5 and CMAQ. A layer averaging (collapsing) scheme is adopted for CMAQ to reduce the computational time of the CMAQ simulations. The effects of layer averaging were evaluated in the VISTAS Phase I modeling effort and found to have a relatively minor effect on the model performance metrics when both the 34 layer and a 19 layer CMAQ models were compared to ambient monitoring data (Morris et al., 2004c).



**Figure A-1.** Nesting of 36-km CMAQ Grid in the MM5 36-km Grid.



**Figure A-2.** Nesting of 12-km Grid in the CMAQ 36-km Grid.



**Figure A-3.** Domain Definition for High Resolution 12-km Grid.

**Table A-3.** Vertical Layer Definition For MM5 Simulations (Left Most Columns), And Approach For Reducing CMAQ Layers By Collapsing Multiple MM5 Layers (Right Columns).

| MM5   |       |          |           |          | CMAQ 19L |       |          |           |          |
|-------|-------|----------|-----------|----------|----------|-------|----------|-----------|----------|
| Layer | Sigma | Pres(mb) | Height(m) | Depth(m) | Layer    | Sigma | Pres(mb) | Height(m) | Depth(m) |
| 34    | 0.000 | 100      | 14662     | 1841     | 19       | 0.000 | 100      | 14662     | 6536     |
| 33    | 0.050 | 145      | 12822     | 1466     |          | 0.050 | 145      |           |          |
| 32    | 0.100 | 190      | 11356     | 1228     |          | 0.100 | 190      |           |          |
| 31    | 0.150 | 235      | 10127     | 1062     |          | 0.150 | 235      |           |          |
| 30    | 0.200 | 280      | 9066      | 939      |          | 0.200 | 280      |           |          |
| 29    | 0.250 | 325      | 8127      | 843      | 18       | 0.250 | 325      | 8127      | 2966     |
| 28    | 0.300 | 370      | 7284      | 767      |          | 0.300 | 370      |           |          |
| 27    | 0.350 | 415      | 6517      | 704      |          | 0.350 | 415      |           |          |
| 26    | 0.400 | 460      | 5812      | 652      |          | 0.400 | 460      |           |          |
| 25    | 0.450 | 505      | 5160      | 607      | 17       | 0.450 | 505      | 5160      | 1712     |
| 24    | 0.500 | 550      | 4553      | 569      |          | 0.500 | 550      |           |          |
| 23    | 0.550 | 595      | 3984      | 536      |          | 0.550 | 595      |           |          |
| 22    | 0.600 | 640      | 3448      | 506      | 16       | 0.600 | 640      | 3448      | 986      |
| 21    | 0.650 | 685      | 2942      | 480      |          | 0.650 | 685      |           |          |
| 20    | 0.700 | 730      | 2462      | 367      | 15       | 0.700 | 730      | 2462      | 633      |
| 19    | 0.740 | 766      | 2095      | 266      |          | 0.740 | 766      |           |          |
| 18    | 0.770 | 793      | 1828      | 259      | 14       | 0.770 | 793      | 1828      | 428      |
| 17    | 0.800 | 820      | 1569      | 169      |          | 0.800 | 820      |           |          |
| 16    | 0.820 | 838      | 1400      | 166      | 13       | 0.820 | 838      | 1400      | 329      |
| 15    | 0.840 | 856      | 1235      | 163      |          | 0.840 | 856      |           |          |
| 14    | 0.860 | 874      | 1071      | 160      | 12       | 0.860 | 874      | 1071      | 160      |
| 13    | 0.880 | 892      | 911       | 158      | 11       | 0.880 | 892      | 911       | 158      |
| 12    | 0.900 | 910      | 753       | 78       | 10       | 0.900 | 910      | 753       | 155      |
| 11    | 0.910 | 919      | 675       | 77       |          | 0.910 | 919      |           |          |
| 10    | 0.920 | 928      | 598       | 77       | 9        | 0.920 | 928      | 598       | 153      |
| 9     | 0.930 | 937      | 521       | 76       |          | 0.930 | 937      |           |          |
| 8     | 0.940 | 946      | 445       | 76       | 8        | 0.940 | 946      | 445       | 76       |
| 7     | 0.950 | 955      | 369       | 75       | 7        | 0.950 | 955      | 369       | 75       |
| 6     | 0.960 | 964      | 294       | 74       | 6        | 0.960 | 964      | 294       | 74       |
| 5     | 0.970 | 973      | 220       | 74       | 5        | 0.970 | 973      | 220       | 74       |
| 4     | 0.980 | 982      | 146       | 37       | 4        | 0.980 | 982      | 146       | 37       |
| 3     | 0.985 | 986.5    | 109       | 37       | 3        | 0.985 | 986.5    | 109       | 37       |
| 2     | 0.990 | 991      | 73        | 36       | 2        | 0.990 | 991      | 73        | 36       |
| 1     | 0.995 | 995.5    | 36        | 36       | 1        | 0.995 | 995.5    | 36        | 36       |
| 0     | 1.000 | 1000     | 0         | 0        | 0        | 1.000 | 1000     | 0         | 0        |

## **Emissions Data**

The base year emissions inventory for VISTAS modeling served as the basis for the ASIP modeling. These data are founded on 2002 Consolidated Emission Reporting Rule (CERR) inventories submitted to VISTAS by participating state or local agencies and compiled by VISTAS emission inventory contractors in NEI Input Format (NIF) 3.0 (MACTEC, 2007). These emissions were reviewed by VISTAS stakeholders and considered complete in January of 2004, with minor modifications submitted since that time. Non-VISTAS state emissions were based on inventories obtained by the Study Team from the other RPOs or EPA and determined to be representative of the 2002 episode year. Mexican and Canadian emissions were based on the latest available inventories obtainable by VISTAS in formats lending themselves to emissions modeling. For purposes of air quality model validation, actual 2002 calendar year emissions for EGU and fire activity were used. For strategy and future year emission runs, "typical year" emissions for these categories were processed for 2002 and the future years.

All emissions were converted to Inventory Data Analyzer (IDA) format and the data were processed for air quality modeling using Version 2.3 of the Sparse Matrix Operating Kernel Emissions (SMOKE) model. Included in these runs were the temporal and speciation profiles and cross-reference data provided with the version 2.3 release of the model augmented with any recommended and approved emission profile data provided by the emissions inventory contractor, obtained from EPA, or prepared by VISTAS prior to initial emissions modeling. Spatial allocation of the emissions was based on profiles and spatial allocation factors developed for the National RPO grid.

Emissions for 2009 and 2018 were obtained by projecting 2002 emissions to the future-years assuming growth and on-the-books (OTB) control measures. Emissions associated with biogenics, typical wildfires, Mexico, Canada, off-shore commercial marine and wind blown dust were held constant between 2002 and the future-years. Future-year SO<sub>2</sub> and NO<sub>x</sub> emissions for EGUs were generated using the Integrated Planning Model (IPM) assuming the CAIR cap and trade program is in place in the states affected by CAIR.

## **Ozone Column Data**

Ozone column data is needed to adjust the incoming solar radiation to account for the amount of ozone from the surface to above the stratosphere. These data come from the Total Ozone Mapping Spectrometer (TOMS) satellite data. TOMS data that is available for 24-hour average and was obtained from <http://toms.gsfc.nasa.gov/eptoms/ep.html>. Day-specific TOMS data is used in the CMAQ radiation model (JPROC) to calculate photolysis rates. The TOMS data were missing or bad for several periods in 2002: August 2-12; June 10; and November 18-19. Thus, the TOMS data for August 1, 2002 was used for August 2-7 and TOMS data for August 13 was used for August 8-12. Similarly, TOMS data for June 9 was used for June 10 and data for August 17 was used for August 18-19. Note that the total column of ozone in the atmosphere is dominated by stratospheric ozone which has very little day-to-day variability.

## **Meteorological Data**

Meteorological data were generated using the MM5 prognostic meteorological model by Baron Advanced Meteorological Systems (BAMS). BAMS operated the MM5 at 5-day increments for 2002 on the 36 km and 12 km grid with a 14 day spin up period at the end of December 2001. Details on the VISTAS Phase II 2002 MM5 modeling can be found in Olerud (2003a,b) and at the BAMS VISTAS website: <http://www.baronams.com/projects/VISTAS/>.

## **Initial and Boundary Conditions Data**

The CMAQ default Initial Concentrations (ICs) were used along with a ~15 day spin up (initialization) period to eliminate any significant influence of the ICs. That is, the model is started approximately 15 days prior to the first day of interest (e.g., January 1, 2002) to allow concentrations to build up in the model to real levels in the atmosphere.

The CMAQ Boundary Conditions (BCs) for the Inter-RPO 36 km grid and the ASIP simulations were based on day-specific 3-hourly averages from a 2002 GEOS-CHEM global simulation model output (Jacob, Park and Logan, 2005). The 2002 GEOS-CHEM output was mapped to the species and vertical layers structure of CMAQ and interpolated to the lateral boundaries of the 36 km grid shown in Figure A-1 (Byun, 2004). Boundary conditions for the 12 km grid were based on CMAQ results from the 36 km grid processed with the CMAQ BCON boundary condition processor.

## **APPENDIX B**

### **Resume**

**Ralph E. Morris**  
**ENVIRON International Corporation**

## **Ralph E. Morris**

### **Education**

- 1979 M.A., Mathematics, University of California, Davis
- 1976 B.A., Mathematics, University of California, Berkeley

### **Experience**

Mr. Morris is the Managing Principal at ENVIRON International Corporation where he directs air quality modeling and analysis, emission inventory development, control strategy evaluation, and regulatory policy analysis projects. He has over twenty-five years experience in air quality issues, with particular emphasis in the development and application of advanced air quality models. Mr. Morris has been using photochemical, particulate matter, acid deposition, and visibility grid and plume models since the 1970's. He has used over 50 different air quality and acid deposition models in over 500 air-quality-related projects. Mr. Morris has working knowledge of atmospheric chemistry, meteorology, physics, emissions, and computer science. He has also had extensive experience in the regulatory and policy analysis aspects of air quality issues. This hands-on experience in a variety of air quality disciplines gives Mr. Morris a broad-based interdisciplinary background that enables him to address a wide range of air quality issues.

Mr. Morris is currently leading or a key participant in several regional modeling and analysis efforts aimed at addressing the regulatory requirements of the new 8-hour ozone and PM<sub>2.5</sub> standards and the requirements of the Regional Haze Rule (RHR). EPA has formed five Regional Planning Organizations (RPOs) consisting of States, Tribes, Federal and Local Agencies and Stakeholders to address the RHR and regional requirements of the new ozone and PM standards. Mr. Morris is Project Manager for the emissions and air quality modeling activities for the Southeastern (VISTAS) and Central (CENRAP) States RPOs, is Co-Principal Investigator for the Western States (WRAP) RPO and is assisting the Midwest RPO in their modeling analysis. In these studies the MM5 meteorological, SMOKE emissions and the CMAQ and/or CAMx air quality models are being applied on continental US domains for annual periods. Mr. Morris is leading the efforts to perform visibility projections for 2018 and 8-hour ozone and PM<sub>2.5</sub> projections for 2009. He is also leading efforts to enhance the CMAQ and CAMx models incorporating the latest science attributes.

Mr. Morris is also currently leading the efforts of several other 8-hour ozone and PM<sub>2.5</sub> modeling studies including those for St. Louis for the States of Missouri and Illinois and for several Southeastern States as part of the Association of States for Integrated Planning (ASIP). Mr. Morris is also involved in RHR Best Available Retrofit Modeling (BART) for several States including Arizona, New Mexico, Nebraska, Nevada, South Dakota, Texas and Utah. Recently, Mr. Morris led the development of several States 8-hour ozone Early Action Compact (EAC) State Implementation Plans (SIPs) that were submitted to EPA in December 2004. These States that submitted 8-hour EAC SIPs include Colorado, Oklahoma, New Mexico, Texas and West Virginia.

After Mr. Morris joined ENVIRON in 1994, he became heavily involved in the eastern U.S. ozone nonattainment problem and directed (with others) the development of ENVIRON's Comprehensive Air-quality Model with extensions (CAMx). Mr. Morris has performed several studies for eastern U.S. Stakeholders (e.g., States, utilities, trade organizations, and other industries) using the CAMx advanced

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ozone apportionment capability to aid in the identification of ozone source-receptor relationships and the design of optimal control strategies for reducing ozone. Mr. Morris is currently directing the development of a new generation of 8-hour ozone modeling databases for several regions including St. Louis, Kansas City, and several locations in Texas.

Mr. Morris is one of the original developers of most photochemical air quality models being used for regulatory decision making in the U.S. today including CAMx, UAM, and UAM-V. At ENVIRON he directed the development of the Comprehensive Air-quality Model with extensions (CAMx) that combines state-of-art science with a modern and modular framework. CAMx has been used for many ozone regulatory applications. Currently it is being updated to include advanced mass balance and sensitivity analysis (Process Analysis and Decoupled Direct Method – DDM sensitivities), inclusion of the treatment of size resolved particulate matter (PM), and inclusion of the treatment of air toxics.

Mr. Morris has also heavily involved in PM<sub>10</sub>, fine particulate, and visibility modeling. He has performed PM<sub>10</sub> modeling as part of the development of State Implementation Plans (SIPs) for the Owens Valley California, Maricopa County (Phoenix) Arizona, Rogue Valley (Medford) Oregon, and Imperial County California. Mr. Morris also directed a study to assist the City of Los Angeles with the development of a PM<sub>10</sub> emission control plan for the South Coast Air Basin (SoCAB) that was included with the 1997 California SIP. Mr. Morris was selected as a member of the EPA Fine Particulate Guidance Workgroup and the SoCAB PM<sub>10</sub> Technical Enhancement Program (PTEP) Modeling Working Group.

During 1986, Mr. Morris also directed the application of the CALMET/CALPUFF PM/Visibility Model as part of the Mount Zirkel Visibility Study (MZVS). Over the past several years Mr. Morris has applied the CALPUFF modeling system to estimate PSD pollutant concentrations, visibility degradation, and acid deposition impacts at sensitive Class I and II areas for several Environmental Impact Statements (EIS) and PSD permits, including:

- The Pinedale Anticline Oil and Gas Exploration Project in southwestern Wyoming;
- The Dakota, Minnesota, and Eastern (DM&E) railway expansion project across Minnesota, South Dakota, and into northeastern Wyoming;
- The North American Power Group (NAPG) electrical line and coal-fired power plant project in northwestern Wyoming;
- The Salt River Project (SRP) Santan energy generation facility expansion in Arizona;
- The Portland Cement Plant modification in Lebec, California;
- The Holnam Lee Island project to build the largest cement plant in the U.S. to be located south of St. Louis, Missouri; and.
- The Intergen Ocotillo Energy Project (OEP) to build a natural gas fired turbine near Palm Springs, California.
- The Moxa Arch Infill gas development project BLM EIS in southwestern Wyoming.
- The Hiawatha gas development project BLM EIS on the Wyoming-Colorado border.

Because of his broad-based technical experience and ability to interpret the policy implications of air quality studies, Mr. Morris was selected by the Environmental Council of States (ECOS) Ozone Transport Assessment Group (OTAG) to review and determine the implications of existing ozone measurement and modeling studies of the eastern U.S.

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Because of Mr. Morris' expertise in ozone and PM model development and application, he has been used as an expert witness in several legal actions, including:

- Minnesota Acid Rain Legislation: In the early 1980s Mr. Morris performed modeling and testified in Minneapolis, MN front of a judge for Northern States Power regarding the impacts of local sources in Minnesota on acid deposition in Minnesota.
- WE Energies Power the Future: In 2004, Mr. Morris performed air quality modeling using CAMx and testified in front of a judge in Madison, WI on the Wisconsin Electric's plans to retire and old and build a new coal fired power plan at the Oak Creek facility. Testimony also included a critical review of CALPUFF modeling performed by the opponents.
- Illinois Power/Dynegy Baldwin NOV: Mr. Morris was an expert witness for Illinois Power through Akin Gump in the US DOJ Notice of Violation case against the Baldwin Power Plant. Mr. Morris prepared expert reports and was deposed on the ozone and PM impacts of the alleged excess emissions including a review and critique of the plaintiffs CALPUFF modeling that found errors and omissions.
- First Energy/Ohio Edison Sammis NOV: Through Akin Gump Mr. Morris was an expert witness for the Sammis NOV case preparing expert reports and being deposed on ozone and PM modeling.
- AEP NOV: Mr. Morris is currently an expert witness for American Electric Power (AEP) through Sidley/Austin in the US DOJ NOV charges against 9 coal-fired power plants in the Midwestern US.

Prior to joining ENVIRON Mr. Morris worked for over 15 years at Systems Applications International (SAI) in San Rafael (now part of ICF Consulting), California, where he was Director of the Advanced Modeling Program, managed model development activities and air quality modeling and analysis studies. His work at SAI included the following:

- Project Manager for a new EPA study to develop a Particulate Matter (PM) and toxic model to be used to: (1) evaluate alternative PM standards; (2) perform PM attainment demonstrations; and (3) estimate toxic deposition onto the Great Waters.
- Principal designer and developer of the new nested-grid version of the Urban Airshed Model (UAM-V), which incorporates the latest state-of-the-art chemistry, deposition, advection/diffusion, computing, grid nesting, and sub-grid-scale plume treatment techniques.
- Project manager and principal investigator in the development of an ozone attainment strategy for the South Coast Air Basin for the city of Los Angeles which was used in the 1994 California State Implementation Plan (SIP).
- Principal investigator and director of the UAM-V photochemical modeling portion of the Lake Michigan Ozone Study (LMOS).
- Project manager and principal investigator in a study for the American Automobile Manufacturers Association (AAMA) to assess the air quality impacts of the adoption of a California-style Low Emissions Vehicle (LEV) program in the Northeast.
- Project manager and principal investigator in a project for EPA OPPE to estimate the air-quality-related benefits (including reduction in ozone, PM<sub>10</sub>, PM<sub>2.5</sub>, acid deposition, nitrification,

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visibility impairment, and human mortality and morbidity) of the 1990 CAAA Title IV NO<sub>x</sub> controls by applying regional acid deposition and oxidant models to the eastern United States.

- Project manager and principal investigator in the EPA Five Cities UAM Study, a landmark study that demonstrated the use of the UAM in five cities for SIP-type applications.
- Principal investigator in coordinating and performing the air quality modeling component of the \$40+ million joint Phase I Auto/Oil Air Quality Improvement Program.
- Project manager and principal investigator in designing the UAM modeling system and documentation and delivery of the EPA regulatory version of the UAM to the EPA.
- Project manager and principal investigator for the EPA Rocky Mountain Acid Deposition Model Assessment project to develop a new model for simulating air quality and acid deposition in complex terrain.

## Professional Memberships

Air Quality Modeling Subcommittee (AQMS) of the Science Advisory Board (SAB)

EPA's STAR Grant Review Committee

Air and Waste Management Association (AWMA)

EPA's Urban Airshed Model (UAM) Guidance Workgroup

South Coast Air Quality Management District (SCAQMD) Modeling Peer Review Group

EPA's Fine Particulate Modeling Guidance Workgroup

## Publications And Presentations

Mr. Morris is principal author of hundreds of technical reports, scientific papers, and conference presentations. Selected papers and reports prepared over the last decade are listed as follows:

Morris, R.E., G. Yarwood, C. Emery, G. Wilson, B. Koo. 2006. "Regional Modeling Using One-Atmospheric Models to Address Regional Haze, 8-Hour Ozone and PM<sub>2.5</sub> Air Quality Issues. Presented at the 99<sup>th</sup> Annual AWMA Conference, New Orleans, LA. June.

Morris, R.E., B. Koo, A. Guenther, G. Yarwood, D. McNally, T. Tesche, G. Tonnesen, J. Boylan and P. Brewer. 2006. Model Sensitivity Evaluation for Organic Carbon Using Two Multi-pollutant Air Quality Models that Simulate Haze in the Southeastern United States. *Atmos. Env.* 40 (2006) 4960-4972.

Morris, R., T.W. Tesche, G. Tonnesen, D. McNally, J. Boylan and P. Brewer. CMAQ/CAMx annual 2002 performance evaluation over the eastern U.S. *Atmos. Env.* 40 (2006) 4906-4919.

Morris, R., C. Emery and G. Yarwood. 2006. Use of an Advanced Hybrid Plume/Grid Photochemical Model to Perform Single Source Assessments for PSD and BART Analysis. Presented at the AWMA Guidelines on Air Quality Models Conference, Denver, Colorado. April 26-28.

Morris, R., S. Lau, B. Koo, A. Hoats and G. Yarwood. 2006. Further Evaluation of the Chemistry Algorithms used in the CALPUFF Modeling System. Presented at the AWMA Guidelines on Air Quality Models Conference, Denver, Colorado. April 26-28.

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- Morris, R., B. Koo and G. Yarwood. 2005. "Evaluation of Multisectional and Two-Section Particulate Matter Photochemical Grid Models in the Western United States." *J. Air & Waste Man. Assoc.*, Vol 55, No. 11, pp1683-1693. November.
- Morris, R., D. McNally, T.W. Tesche, G. Tonnesen, J. Boylan and P. Brewer. 2005. "Preliminary Evaluation of the Community Multiscale Air Quality Model for 2002 over the Southeastern United States." *J. Air & Waste Man. Assoc.*, Vol 55, No. 11, pp1694-1708. November.
- Morris, R., B. Koo, G. Mansell, G. Yarwood, G. Tonnesen, C.J. Chien, M. Omary. 2005. "Annual Application Of Regional Particulate Matter Photochemical Grid Models To The Central Us To Support The Requirements Of The Regional Haze Rule." Presented at the International Aerosol Conference (AAAR) 2005, Austin, Texas. October.
- Morris, R., D. McNally, T. Tesche, G. Tonnesen, J. Boylan, P. Brewer. 2005. "Use Of The CMAQ Modeling Systems For Estimating Visibility Progress In The Southeastern Us For Complying With The Requirements Of The Regional Haze Rule." Presented at The 4th Annual CMAS Models-3 Conference, Chapel Hill, N.C. September
- Morris, R.E., S. Lau, B. Koo. 2005. "Evaluation of the CALPUFF Chemistry Algorithms." Presented at the 98<sup>th</sup> Annual Air and Waste Management Conference, Minneapolis, MN. June.
- Morris, R.E., G. Yarwood, C. Emery, G. Wilson and B. Koo. 2005. "Recent Advances in One-Atmospheric Modeling Using the Comprehensive Air-quality Model with Extensions." Presented at the 98<sup>th</sup> Annual Air and Waste Management Conference, Minneapolis, MN. June.
- Morris, R.E., B. Koo, G. Yarwood, C. Emery, G. Wilson. 2005. "Regional Modeling of Particulate Matter (PM), Ozone and Visibility using the CMAQ and CAMx Photochemical Grid Models." Presented at Atmospheric Sciences and Air Quality Conference (ASAQC), San Francisco, CA. April.
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